Third United Nations International Conference on the Peaceful Uses of Atomic Energy

A/CONF.28/A/431
JAPAN
February 1964
Submitted in: ENGLISH and FRENCH

Confidential until official release during Conference

Abstract

On the Thermal Fatigue Behavior of Fuel Sheath Material subject to Constrained Deformation caused by Core Material.

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Sheath and core materials bonded together in a fuel element into a single body are nevertheless subjected to different conditions of temperature and atmosphere. When the rigidity of the sheath material is lower than that of the core material, the sheath would yield to dimensional changes of the core during use in reactor and undergo constrained deformation. Hence, for fuel element design, safety analysis and use, it should be very important to study this constrained deformation from the standpoint of thermal fatigue behavior.

For the present study a universal thermal fatigue testing machine of the authors' original design was used, this machine can be utilized not only for investigating such constrained deformation but also other thermal fatigue phenomena in general.

The experimental method is to fix the core and sheath separately, and have the thermal strain induced by the difference in thermal cycling temperature range accurately transmitted to the sheath, thus permitting the induced stress behavior, microstructure and failure to be observed.

1. Experiments on 2S Aluminum.

2S Aluminum kept at 75°C was subjected to constrained deformation caused by β-quenched uranium undergoing thermal cycling in the range 110°C- 550°C. It was found that the maximum value of the stress induced in the aluminum decreases gradually up to 40 cycles and then becomes constant. Furthermore the yielding stress of the aluminum decreases with increasing number of cycles with corresponding lower temperature of the uranium.

Constant strain cycling tests were also carried out at several rates

of increasing strain provoked by thermal growth of uranium. The results were as follows.

a. Increasing strain of any rate augments local deformation in aluminum.

b. The stress change in aluminum depends upon the rate of increasing strain.

c. Between number of cycles to fatigue failure, N, and rate of increasing strain, $\Delta\varepsilon$, there exists a relationship, $\Delta\varepsilon \cdot N^n = C$, where C and n are constant. These results are discussed from considerations of structural change in the aluminum.

2. Experiments on Magnox A-12 alloys.

Magnox A-12 alloy cycled between 150°C and 450°C was subjected to constrained deformation caused by uranium undergoing cycling between 190°C and 575°C, with the same cycling period for both materials. It was found that compressive stresses occurred in the Magnox at higher regions of the temperature range, and that lengthening the cycling period from 0.5 to 4 hr. per cycle promoted tensile creep and stress relaxation in the lower temperatures. Finally some ordinary thermal fatigue tests for Magnox were carried out in five steps of lower temperature limit ranging from 125°C to 325°C and with common temperature interval of 200°C. With higher temperature limits, for instance 525°C, the decrease of fatigue life was quite marked. From this the authors have concluded that in such cases the well-known Coffin's low was no longer satisfied, and that to explain the effect a concept involving thermal activation might be introduced for higher temperature ranges.

Appendix.

The authors have investigated deformation and changes in dimension, strength and microstructure during simple thermal cycling of various metals and alloys for reactor use, and many interesting characteristics have been newly found, some of which proved to be useful keys considering the basic concept of thermal fatigue behavior of the sheath materials named above.